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ABSTRACT

High risk students in college chemistry are often identified by low mathematics SAT scores, low American Chemical Society Toledo scores, and secondary school chemistry grades. This study was designed to identify additional variables that can be used at the community college level as predictors of success in chemistry. The study compared students' mid-semester and final grades in two levels of general chemistry with: (1) their level of intellectual development; (2) attainment of science process goals; (3) background in laboratory science, chemistry, physics and algebra; (4) attitudes toward science, mathematics and chemistry; (5) grade expectancy; (6) cognitive style; (7) sex; and (8) age. Of the predictors of success identified for the introductory chemistry class, the best predictors were grade point average (GPA) and prior chemistry background. The successful student in introductory chemistry was older, had a better grasp of science process skills, and had good algebra grades. The analysis identified 13 predictors of success in the general chemistry courses; the single best predictor for success was GPA. High scores on the Test of Logical Thinking (TOLT) and the Test of Integrated Process Skills (TIPS) were also significant predictors. (TW)

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IN COMMUNITY COLLEGE GENERAL CHEMISTRY COURSES

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at the Annual Meeting of the
National Association for Research in Science Teaching

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A Study of Factors Affecting Student Performance
in Community College General Chemistry Courses.

Historically, college chemistry courses have had high attrition rates, due in part to the poor preparation students have had for these courses (Rowe, 1982). Studies conducted at the university level have found that if high risk students (as identified by low math SAT scores, low American Chemical Society Toledo scores, and secondary school chemistry grades) are given some type of remediation they can successfully complete their required chemistry courses (Craney & Armstrong, 1985; Pickering, 1977). However, identifying (and consequently assisting) high risk students at community colleges is difficult since SATs and transcripts are usually not available, especially if they are open-door institutions.

Community colleges provide a vital link to universities and other pre-professional training programs. However, unlike these programs, many community colleges have no entrance requirements. Consequently, students are often poorly prepared for college level coursework. Lack of adequate placement testing compounds the problem. Student learning problems not identified at this level may result in difficulties and even failure in attaining educational goals.

This study was designed to find additional factors that can be used at a community college which might be predictors of success in chemistry or that might differentiate between low achievers and high achievers. The study compared students' mid-semester and final grades in two levels of general chemistry with their level of intellectual development, attainment of science process skills, background in lab science, chemistry, physics and algebra, attitude towards science, math and chemistry, grade expectancy, cognitive style, sex and age. In addition, the study determined if differences in attitudes, cognitive styles, and cognitive abilities resulted in corresponding differences in grade achievement.

Theoretical Base

Students attempting chemistry need to be functioning at the formal operational level, as defined by Piaget (Herron, 1975). However, there is considerable evidence which indicates that many adults never reach this level (Lawson, 1985). One valid and reliable measure of intellectual development is the Test of Logical Thinking (TOLT). The TOLT is used to classify students as formal operational, concrete operational, or transitional by measuring the ability to control variables, and to use combinational reasoning, probabilistic reasoning, correlational reasoning, and proportional reasoning (Tobin & Capie, 1981). TOLT scores range from 0 to 10. The information gained from this test can be used to develop intervention related to chemistry learning problems. Studies have shown that practice in solving problems requiring these reasoning skills can result in growth in cognitive ability (Lawson, 1985).

The Test of Integrated Process Skills (TIPS) is a valid and reliable measure of a students' ability to operationally define variables, state hypotheses, interpret graphs, and design investigations (Dillashaw & Okey, 1980). TIPS scores range from 0 to 36. The skills measured by the TIPS should be learned in secondary school lab science courses. The test can be used to learn if previous attainment of these skills can be correlated with achievement in chemistry.

There is increasing emphasis in the literature on how students process information as they learn science concepts and processes. The Personal Style Indicator (PSI) is a forced rank instrument that can be used to identify students' preferred cognitive style. The style categories include affiliative, creative, enterprising, ordered and investigative (Cotroneo, 1983). The scores range from 8 to 38 in each category, with lower scores indicating a student's preference for a particular cognitive style. Data on individual cognitive styles is useful in planning instructional methodology and remediating student learning problems.

The classes that were used in this study have high attrition rates. The investigators selected the personal variables discussed in this section to compare with the overall attrition rate in an effort to better understand the underlying causes. Many chemistry instructors believe that prior problem solving experiences and math skills increase a student's chances for success in chemistry (Genyea, 1983; Goodstein, 1983). The investigators selected information about the students' algebra, chemistry and physics backgrounds to evaluate the students preparation for the problem solving tasks commonly found in chemistry courses. In addition to background information, the students were asked to evaluate their confidence in their ability to handle chemistry, and their attitude towards math and science in general. The investigators hypothesized that students' motivation for success, as well as their past college experiences, should also indicate their chances of success in chemistry. Information about grade point averages, majors, and number of withdrawals on student college transcripts was collected and compared with the student's success in chemistry.

Procedure

During the first week of Fall 1985 classes at a northeast Florida community college, students enrolled in an introductory chemistry course with a lab (introductory level general chemistry for allied science students, a group composed of 49 male and 63 female students) and in a general chemistry course with a lab (46 male and 21 female students) completed a data sheet, the TOLT and the TIPS. The data sheet asked the students to provide information regarding their age, sex, lab science background, courses completed in chemistry, algebra and physics (including when taken and grade received), and the grade they expected to achieve in the course. The students were asked to indicate their level of agreement (in terms of strongly disagree, disagree, agree or strongly agree) with statements concerning their attitudes towards math, science and chemistry. Each student's college GPA and number of withdrawals prior to enrollment in this course was provided by Student Development Services. The PSI was administered in the last four weeks of classes to obtain information about the students completing the course.

Mid-semester and final grades were compared with these variables using multiple regression analysis to study predictors of success. The factors differentiating high achieving students (those earning As and Bs) from low achieving students (those earning Cs and below, or that withdrew) were examined by performing chi-square analysis and analysis of variance (ANOVA). The same statistical tools were used to differentiate successful students (those earning C or better grades) from unsuccessful students (those earning D or lower grades, or that withdrew).

Results and Discussion

During the Fall 1985 term, 16% of the introductory chemistry students and 18% of the general chemistry students had withdrawn from classes by mid-semester. These figures rose to 21% and 30%, respectively, by the end of the term. In addition to this fairly high attrition rate, these courses had high failure rates. The combined failure/attrition rate was 48% in the introductory chemistry group and 61% in the general chemistry group. These figures underline the importance of finding predictors for success in chemistry that are useful at community colleges.

Predictors of Success in Introductory Chemistry

The introductory chemistry course is a two semester course designed for allied science students (nursing, medical technology, engineering technology, fire science, etc.) but it is also taken by science and engineering majors lacking sufficient preparation for the general chemistry course. The science and engineering majors made up 35% of the 112 students in this group. 27% of the students had not chosen a major at the start of the term. The remaining 38% were declared allied science majors. The science and engineering majors achieved slightly higher grades as a group than the other majors (Pearson's $R=0.18$, $p=0.026$).

Multiple regression analysis identified 16 predictors of success in the introductory chemistry course. The analysis was done on both the mid-semester grades and the final grades. The mid-semester grade was based on the average of two or three exams, resulting in a 0 to 100 grading scale. The final grade, which included both the exam average and the lab average, was based on a 5 point grading scale (5=A, 4=B, 3=C, 2=D, 1=F, and 0=W). The relative contribution of each predictor in explaining the variance in the mid-semester grades and the final grades differs considerably. The order of importance of each variable is indicated in the column labeled order. Lab science background contributes very little to the variance in the mid-semester grades and contributes over 20% to the variance in the final grades. This result is not as surprising as it may seem, when the absence of lab grades in the mid-semester average is considered. In the first half of the semester the students use their proportional reasoning skills to solve density and metric problems. They also are asked to consider abstract concepts like atomic theory and bonding. The grades on the tests given in the first half of the term would be highly correlated with the TOLT which measures these skills. The second half of the course is less abstract and uses more algorithms in problem solving. The exam average of the second half of the course (and the lab average) when combined with the exam average with the first half resulted in a smaller contribution of the TOLT to the overall variance in the final grade (see Table 1). Caution should be used when generalizing the

Insert Table 1 about here

multiple regression results in this report. Intact classes were used in this study. These results are most useful for identifying the relative effectiveness of predictors.

The student's GPA was the single best predictor of success in the introductory chemistry courses, explaining 42% of the variance in the final grades. All of the students in this sample were at least in their second term, and all of their GPAs were above zero. Apparently the factors that result in high GPAs also result in success in chemistry. The students were separated into three groups (GPAs from 0 to 1.9, GPAs from 2.0 to 2.9, and GPAs from 3.0 to 4.0) and their final grades were examined by chi-square analysis. Students that achieved success in chemistry were defined as those students with final grades of C or better. The chi-square was 13.1 ($p=0.0015$), indicating that there was a significant difference in the number of students that achieved success in each of the three groups of GPAs. 72% of the GPAs between 3.0 and 4.0 passed chemistry, 53% of the students with GPAs between 2.0 and 2.9 passed, and only 9.0% of the students with GPAs under 2.0 passed. The ANOVA data for the variables with significantly different means between the successful and unsuccessful students in the entire study is found in Table 2. ANOVA results for the general chemistry group will

Insert Table 2 about here

be discussed in the next section. The ANOVA of GPAs was significant at the 0.005 level. A significant difference in the number of students with final grades of A or B was found when the students' GPAs were grouped as before and studied using chi-square. (Chi-square=18.9, $p=0.0001$) 69% of the students with GPAs greater than 3.0 achieved an A or B grade in chemistry. Only 23% of the students with GPAs between 2.0 and 2.9 achieved an A or B grade, and no students with lower GPAs achieved A or B grades. In fact, only 4% of the introductory chemistry students with GPAs below 2.5 achieved A or B grades in chemistry.

Prior chemistry background was also a useful differentiator, with a chi-square of 4.2 ($p=0.0405$). 71% of the students who successfully completed chemistry had had either high school chemistry or a liberal arts chemistry course, or were repeating this course. 60% of the students with no prior chemistry experience failed. These figures are significant because the introductory chemistry course assumes no prior chemistry knowledge. The previous chemistry course's grade was not a significant differentiator in this study. When the final grades of the students that had A or B grades in their last chemistry course were compared with the grades of the other students using chi-square, no significant difference was found. In fact, almost 50% of the students with A or B grades in their last chemistry course failed or withdrew. This lack of usefulness of the earlier chemistry grade in predicting the final chemistry grade should be considered cautiously in that the earlier chemistry grades were obtained using "self-report". This community college has no requirement for high school transcripts, so these grades were unverifiable. This is a common problem among "open-door" institutions, and frequently results in students being misplaced into courses because of the students' somewhat faulty memories. A recent study of a similar course at a four year college produced a much better correlation between high school chemistry grades and final grades ($R=0.39$). The grades were taken from transcripts and the sample was large (304 students) (Craney & Armstrong, 1985). However, the transferability of these results to community colleges is questionable. Students entering into a four year college are usually selected because of their high SAT or ACT scores (the mean math SAT score for this group was 501). These scores may reflect better backgrounds in math and sciences, resulting in a more homogeneous group of students than the typical community college class. Community college classes tend to be much more heterogeneous, reflecting a wide variety of backgrounds and skills.

Surprisingly, the algebra grade did not significantly contribute to the variance in the final grade, although it correlated with the final grade (Pearson's $R=0.30$, $p=0.00$). This may be due to the high intercorrelation of this variable with the other variables that were effective predictors. The correlation of the algebra grade with math attitude was 0.33 ($p=0.00$), was 0.17 ($p=0.03$) with the TOLT, and 0.35 ($p=0.00$) with the TIPS. This problem of multicollinearity is briefly discussed by Kerlinger and Pedhazur (1973) as being the source of anomalous multiple regression results, as well as great difficulties in interpretation of the beta weights. A significant difference in the final grades of students with A or B algebra grades as compared to lower algebra grades was found using chi-square (chi-square=5.1, $p=0.0233$). 63% of the students with A or B algebra grades passed chemistry, while only 41% of the students with lower grades (or no algebra coursework) passed. A significant difference in the number of students with final grades of A or B was found when the students' algebra grades were grouped as before and examined using chi-square (chi-square=7.39, $p=0.007$). 72% of the A or B chemistry students were also A or B algebra students. 84% of the C or below algebra students were C or below chemistry students or withdrew from the course.

The ANOVA data indicated that there was a significant difference in the means of successful and unsuccessful students on the TIPS test. The TIPS scores were correlated with a student's confidence in his ability to handle chemistry ($R=0.26$, $p=0.00$), his grade expectation ($R=0.43$, $p=0.00$), and his GPA ($R=0.34$, $p=0.00$). This strong intercorrelation among the predictors may help explain why the TIPS accounts for such a small percentage of the overall variance in the final grades, even though it is highly correlated with the grade itself.

The successful student in introductory chemistry can be characterized as being older, having a better grasp of science process skills as evidenced by the TIPS score, having a higher GPA, having good algebra grades, and being more likely to complete a course (as evidenced by the number of withdrawals prior to this course).

Predictors of Success in General Chemistry

The general chemistry course is designed to prepare science and engineering majors for advanced courses in chemistry and chemical engineering. Because of its intent, this course is traditionally more demanding of its students than the introductory course. A prior course in chemistry (either high school chemistry or the introductory course) and college algebra (or two years of high school algebra) are prerequisites for this course.

Multiple regression analysis identified 13 predictors of success in the general chemistry courses (see Table 3). Again caution should be used when

Insert Table 3 about here

generalizing the results of this analysis for the reasons discussed previously.

The students' GPA was the single best predictor of success in this sample. The students at this college rarely are able to take this course in the first term of their freshman year because of deficiencies in their backgrounds. Six students were in their first term in this sample and all but one failed or withdrew. There was a significant difference in the means of successful and unsuccessful students. The summary of the ANOVA data is found in Table 2. The successful students' mean GPA was over a grade point higher than the unsuccessful students' mean. The GPAs were separated into groups as described previously and the final grades were examined by chi-square analysis. The chi-square was 21.2 ($p=0.000$). 74% of the students with 3.0 to 4.0 GPAs passed and 34% of the students with 2.0 to 2.9 GPAs passed. No students with GPAs below 2.0 passed. A significant difference in the number of students with final grades of A or B was found when the students' GPAs were grouped as above and studied using chi-square (chi-square=11.9, $p=0.003$). 48% of the students with 3.0 to 4.0 GPAs achieved A or B chemistry grades and only 18% of the students with 2.0 to 2.9 GPAs achieved A or B grades.

Males composed 69% of this sample. This uneven balance in the number of each sex in the sample may explain the large contribution of sex in explaining the overall variance in final grades. There was no significant difference in the means of the males and females, nor was the chi-square significant.

Both the TOLT and TIPS means were significantly different between successful and unsuccessful students. Together they account for almost 6% of the variance in the final grades. There was also a significant difference in the TOLT and TIPS means of high achieving (A or B) students and low achieving students. The A and B chemistry students did significantly better on both tests than the students earning lower grades. The ANOVA data for the TOLT was: Mean and standard deviation of A and B students - 7.7 (2.8), mean and standard deviation of other students - 6.0 (2.7), $F = 4.5$, and $p=0.0369$. The ANOVA data for the TIPS was: Mean and standard deviation of A and B students - 30.1 (3.0), mean and standard deviation of other students - 26.8 (5.6), $F = 4.9$, and $p=0.0308$.

Over 87% of the students in this sample have taken college algebra or a course in the calculus, and the 13% who had not taken either course failed or withdrew. The chi-square on algebra background was significant (chi-square=4.3, $p=0.0382$). The grade itself, however, accounted for a very small percentage of the variance in final grades.

The grade earned in the prior chemistry course was an important differentiator between students with A or B final grades and the other students. The chi-square was 3.1 ($p=0.08$). 86% of the students who earned C or below grades in their last chemistry course earned C or below in this course or withdrew.

In summary, the successful general chemistry student in this sample was characterized as having had either college algebra or the calculus, having a high GPA, and having high TIPS and TOLT scores.

Personal Style Indicator

The Personal Style Indicator (PSI) was administered after the withdrawal deadline in the last month of the semester. For this reason, it cannot be considered as a predictor for success, although inclusion of the PSI produces an increase of almost 6% in the explained variance in the final grades of both groups. No significant correlations and ANOVA data were found in the introductory chemistry group. The following results were from analysis of the 32 remaining general chemistry students' PSI results.

The correlation between the PSI(ordered) and the final grade average was $-0.55(p=0.00)$. The correlation is negative because smaller values of the indicators mean the students have a greater preference for this type of learning style. Cotroneo (1983) states that students who prefer this learning style prefer information to be provided and processed in a logical, orderly fashion. Chemistry is taught in a logical progression from simple to complex, with very little allowance for students to be divergent with the information presented. (How many correct answers are there to questions about stoichiometry, bonding and atomic theory in the freshman chemistry course?) In Table 4 it can

Insert Table 4 about here

be seen that there is a significant difference in the PSI(ordered) means among the final grade groups. The A students' mean was significantly lower and had a more narrowly defined range than any of the other groups (10 to 17). None of the other 4 indicators had significant differences among the means of the various grade groups. However, there are strong correlations between final grades and scores with two of these indicators. Pearson's R for PSI(investigative) was -0.25 ($p=0.08$) and the R for PSI(creative) was $0.47(p=0.00)$. The positive correlation between PSI(creative) and the final grade can be related to the highly structured instructional methods used in teaching this course. The less creative student achieved higher grades. This result should be considered cautiously. The students were asked to rank each word in a group of five words according to the relative importance of that word to him (thus assigning values of 1 through 5 to each word). This process was repeated with eight groups of words. Students who consistently assigned values of 1 or 2 to words indicating preference for order had much higher overall PSI values for the other indicators. A learning style indicator that does not use the forced rank method might not lead to the (hopefully) false conclusion that students that do well in chemistry are not creative.

Implications for Teaching Science

This study has identified variables available to all teaching institutions that can be used to predict a student's performance in chemistry. The students that are identified as low achievers (high risk) can then be offered course advising and some type of appropriate intervention. This community college will be placing the predicted low achievers in introductory chemistry into a special remedial chemistry problem solving course. This remedial course, in the process of being developed at this time, will use the information gained from this study. Problems will be designed to specifically improve students' ability to do proportional reasoning, one of the most important reasoning skills in chemistry and one in which 37% of the students taking the TOLT in this study were unable to do. Other areas of weakness as gleaned from TIPS and TOLT, as well as the cognitive style results, will be used in the course design. Predicted low achievers in general chemistry will be advised to enroll in introductory chemistry first.

Instructors of chemistry will also be able to use the information gained from the study to help identify students' weak areas as they become evident during the term. Once aware of deficiencies, an instructor will then be able to give special attention to correcting them. Deficiencies that are left uncorrected will become pre-instructional knowledge that will interfere with learning in other courses. This concern is especially critical at the community college level. Many community college students do transfer to universities where transition problems are often attributed to lack of preparation at the community college.

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TABLE 1

Multiple Regression Analysis of Predictors
for the Introductory Chemistry Courses

Predictor	Mid-Semester Grades			Final Grades		
	Order	R	% Unique Variance	Order	R	% Unique Variance
GPA	1	0.55	30.14	1	0.65	41.72
Lab Science Background	9	0.08	0.32	2	0.47	20.33
Chemistry Attitude	17	0.01	0.05	3	0.10	6.04
Age	15	0.26	0.07	4	0.38	4.52
Grade Expectations	5	0.10	1.59	5	0.16	2.88
TOLT	2	0.55	14.20	6	0.45	2.86
No. of Withdrawals	14	-0.08	0.09	7	-0.10	1.43
Science Attitude	8	0.29	0.82	8	0.30	1.04
Chemistry Background	3	0.18	3.76	9	0.28	1.00
Major	6	0.10	1.21	10	0.17	0.36
Chemistry Confidence	4	0.18	1.75	11	0.12	0.31
Sex	16	-0.05	0.07	12	0.10	0.16
Physics Background	7	0.10	1.15	13	0.17	0.11
TIPS	12	0.27	0.11	14	0.39	0.10
Math Attitude	10	0.29	0.23	15	0.27	0.07
Chemistry Grade	13	0.17	0.10	16	0.33	0.01
Algebra Grade	11	0.20	0.15	NS	NS	NS
% of Variance Explained:		74.70		82.93		

TABLE 2

ANOVA Data of Successful and Unsuccessful Chemistry Students

Variables	Introductory Chemistry (112)			General Chemistry (67)		
	$\bar{X}_a$ (SD) (58)	$\bar{X}_b$ (SD) (54)	F(p)	$\bar{X}_a$ (SD) (26)	$\bar{X}_b$ (SD) (41)	F(p)
Age	25.0(7.5)	22.7(5.3)	3.4(.068)	24.4(4.8)	23.2(6.0)	0.7(.417)
TIPS	27.4(4.5)	25.6(4.6)	10.7(.002)	29.5(3.1)	26.3(6.0)	6.5(.013)
TOLT	5.9(2.7)	5.1(6.1)	0.8(.384)	7.3(2.8)	5.8(2.7)	4.6(.035)
Mid-Semester Grades	76.1(14.4)	61.4(17.4)	21.4(.000)	78.1(9.5)	51.1(17.5)	49.2(.000)
GPA	2.9(0.6)	2.4(0.8)	8.2(.005)	3.1(0.5)	2.0(1.1)	26.4(.000)
No. of With- drawals	1.7(2.2)	2.6(2.8)	2.8(.099)	1.9(3.1)	3.3(5.5)	1.4(.239)

NOTE: $\bar{X}_a$: Means of successful students
(SD): Standard deviation

$\bar{X}_b$: Means of unsuccessful students
(N): Number of students in group

TABLE 3

Multiple Regression Analysis of Predictors
for the General Chemistry Courses

Predictor	Mid-Semester Grades			Final Grades		
	Order	R	% Unique Variance	Order	R	% Unique Variance
GPA	1	0.69	47.36	1	0.72	52.02
Sex	4	-0.15	2.48	2	-0.31	14.91
TIPS	6	0.47	1.07	3	0.45	5.26
Chemistry Attitude	3	-0.16	4.92	4	-0.08	3.88
Math Attitude	9	0.07	0.87	5	0.24	2.97
Age	2	0.43	11.34	6	0.40	1.92
Chemistry Confidence	11	0.07	0.67	7	0.02	0.87
TOLT	12	0.36	0.49	8	0.42	0.57
Chemistry Background	16	0.09	0.27	9	0.09	0.39
Major	13	-0.15	0.40	10	-0.19	0.14
Algebra Grade	10	0.25	0.83	11	0.43	0.09
No. of Withdrawals	15	0.12	0.29	12	-0.03	0.07
Science Attitude	8	-0.06	0.91	13	-0.02	0.04
Chemistry Grade	14	0.17	0.38	NS	NS	NS
Grade Expectations	7	0.21	0.96	NS	NS	NS
Physics Background	5	0.18	1.19	NS	NS	NS
% of Variance Explained:		85.92				83.12

TABLE 4

ANOVA Data of the PSI Results of General Chemistry Students

Indicator	Means of Each Final Grade Group				F	p
	$\bar{X}_A$ (SD)	$\bar{X}_B$ (SD)	$\bar{X}_C$ (SD)	$\bar{X}_{DFW}$ (SD)		
Ordered	14.3(3.8)	22.0(4.3)	24.6(7.4)	28.5(6.1)	3.5	0.020
Creative	28.0(3.5)	27.8(2.9)	25.8(6.0)	22.0(6.7)	1.9	0.142
Enterprising	27.0(3.0)	24.1(5.7)	24.9(7.9)	23.9(3.0)	0.2	0.957
Investigative	20.0(7.0)	20.8(6.8)	21.6(3.7)	23.6(3.6)	0.9	0.467
Affiliative	28.7(1.5)	24.0(9.1)	21.9(7.7)	23.4(5.9)	0.7	0.628